Available online at www.sciencedirect.com

ScienceDirect

APCBEE Procedia 10 (2014) 54 – 58

Procedia APCBEE

www.elsevier.com/locate/procedia

ICESD 2014: February 19-21, Singapore

Radiological Monitoring of Borehole in Dei-Dei, Abuja, North Central Nigeria

O. Maxwell[a,*], H. Wagiran[a], N. Ibrahim[b], S. K. Lee[c] and S. Sabri[d]

[a]*Department of Physics, Faculty of Science, Universiti Teknologi Malaysia, 81310, UTM, Skudai, Johor Bahru, Johor, Malaysia*
[b]*Faculty of Defence Science and Technology, National Defence University of Malaysia, Kem Sungai Besi, 57000, Kuala Lumpur, Malaysia*
[c]*Infocomm Research Alliance, Universiti Teknologi Malaysia, 81310, UTM, Johor Bahru, Johor, Malaysia*
[d]*Department of urban and Regional Planning, Faculty of Built Environment, Universiti Teknologi Malaysia, 81310, Johor Bahru, Malaysia*

Abstract

Inhabitants in Dei-Dei area of Abuja consume groundwater that recharges from different lithologic units of subsurface structures due to inadequate public water supply.The water is consumed untreated and during drilling, it cuts across so many rock formations, to extents constitute radioactive elements which are to be evaluated. Vertical Electric Sounding and Shuttle Radar Topography mission was used to determine the structure of electric conductivity and map lineaments.Hydrogeologically motivated borehole with geophysical log data was drilled. Activity concentrations were analysed using high resolution co-axial HPGe gamma spectrometer system. The activity concentrations ranges from 45± 2 to 98 ± 6 Bq kg^{-1} for ^{232}Th, 18 ± 2 to 37 ± 4 Bq kg^{-1} for ^{238}U and 236 ± 32 Bq kg^{-1} to 1195±151 Bq kg^{-1} for ^{40}K. Structurally, fractured interconnectivity attributed to low levels in some layers. Activity levels are within the limits, requires research within groundwater activity levels and rock geochemistry.

Selection and peer review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society

Keywords: Abuja, Borehole, Vertical Electrical Sounding (VES), Shuttle Radar Topography Mission (SRTM), Natural Occurring Radionuclides Materials (NORM)

1. Introduction

* Corresponding author.
E-mail address: maxico3333@yahoo.co.uk.

Selection and peer review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society
doi:10.1016/j.apcbee.2014.10.015

Natural radioactivity (^{238}U, ^{232}Th and ^{40}K) from the ground surface relate to the primary mineralogy and lithological compositions of vertical profiles, and the secondary weathered materials. The environmental radiation are related to the geological composition of each lithologically separated area, and to the content in ^{238}U, ^{232}Th and ^{40}K of the rock from which soils originate in each area, [1-2]. Naturally occurring radioactive materials (NORM) are found throughout the earth's crust, and they form part of the natural background radiation to which all humans are exposed,[3]. The presence of these (NORM) in soil, rocks, water, and air, along with cosmic radiation result in continuous and unavoidable internal and external radiation exposures of all humans. In Abuja, the case for conjunctive use of surface and groundwater supply, where available, to meet the ever increasing demand cannot be over-emphasized. Since the city growth is not in phase with the public water supply (waterboard), to defray the deficit, people look for alternative source (Borehole) to argument the demand for water which is inadequate. In the cause of drilling processes, it cuts across so many rock formations; to some extents, these rocks constitute radioactive elements especially granitic rocks found in basement terrain areas like Abuja. The water is being consumed without treatment. The objective of this study, therefore, is to determine the activity concentration of ^{238}U, ^{232}Th and ^{40}K in sequential lithological units to the groundwater-bearing rocks (aquifer) of varying depths, 70m in Dei-Dei. The coordinates of Dei-Dei borehole site is Lat: 9^{o} 6'52"N and Log: 7^{o} 15'39"E (Dei-Dei).

2. Geology and hydrogeology of the Study Area

The area of study forms part of the Basement Complex of northcentral Nigeria; with lithologic units falling under three main categories, which include (1) Undifferentiated migmatite complex of Proterozoic to Archean origin, (2) Metavolcano-Sedimentary rocks of Late Proterozoic age and (3) Older Granite Complex of Late Precambrian - Lower Paleozoic age, also known as Pan-African Granites. All these rocks have been affected and deformed by the Pan-African thermotectonic events. Detailed reports of the lithological description, age, history, structure and geochemistry of the Basement Complex of Nigeria are given in [4-5]. The geologic map of the study area is discussed elsewhere, [5].

2.1. Method of Vertical Electrical Sounding (VES) and Shuttle Radar Topography Mission (SRTM)

The Schlumberger configuration in vertical electrical sounding (VES) was used to determine the structure of the electric conductivity. Vertical electrical sounding probes the vertical variation in resistivity of the subsurface, thereby indicating the presence of fluid and ionic concentration in the subsurface materials, degree of fracturing of the bedrock; all of which would help in making the choice for a feasible site for constructing a successful borehole. The Shuttle Radar Topography Mission (SRTM), a single pass interferometry mission flown in February 2000, generated elevation data at 90m resolution for 80% of the Earth's surface in C-band. The SRTM-DEM data was subjected to hillshading procedure using Idrisi 32 software to enhance linear features that could be major regional fractures, [5]

2.2. Interpretation of VES and SRTM in the Study Area

Geophysical investigation was conducted to locate the suitable sites for drilling, also structures that control the aquifer and depth to the basement terrain groundwater. One sounding was made in the study areas to choose the dense populated zone.Vertical Electrical Sounding (VES) was carried out at the location of the study area and the results obtained were integrated with structural data generated from hill shaded Shuttle Radar Topographic Mission (SRTM) data [5]. The VES plot profile is reported elsewhere, Figure 8, [6]. The interpretation of the data obtained from the sounding revealed that six aquiferous geoelectrical layers overlie the fractured basement, weathered, with maicaceous sandy clay.

A total of 88 lineaments (fractures) were extracted from the hillshaded SRTM image of the area, their orientation and distribution is represented on a lineament map and on a rose diagram, respectively. The dominant fracture trend for the area is NNE – SSW and N – S, which corresponds to the Pan-African trends in the Basement Complex of Nigeria, [5]. The fractures exist and interconnect in the study area and could serve as pathway for radionuclide transport/mobility.

3. Materials and Methods

3.1. Sampling and Sample Preparation

A total of eleven samples collected during drilling of borehole by cutting methods, [5], they were dried at 105^{o}C each overnight, crushed and pass through 250µm Sieve mesh. The fine powdered samples were homogenized, and carefully weighed using an electronic balance with a sensitivity of 0.01g.

The powdered samples were packed in standard 500 mL Marinelli beakers and labelled accordingly with an indelible marker. The samples were sealed and stored for four weeks to achieve secular equilibrium between radium and its progeny [5-7].

3.2. Experimental Method for γ- Spectroscopy

The gamma ray spectroscopy consists of a high purity germanium (HPGe) detector with a counting efficiency of 20%, with a resolution of 1.8 keV for 1332 keV gamma ray emission of ^{60}Co. The detector used in these measurements was a Canberra GC2018 with Genie-2000 software. The detector was cooled by liquid nitrogen and pre-amplifier were placed inside a lead shield to reduce background radiation [7].Under the conditions of secular equilibrium, ^{232}Th concentration was determined from the ^{208}Tl using the 583 keV peak and ^{228}Ac by using the 911 keV peak. ^{238} U was determined from the average concentrations of the ^{214}Pb by using the 352 keV peak and ^{214}Bi by using the 609 keV peak. The 1460 keV peak was used to determine the concentration of ^{40}K. Each sample was put into a shielded HPGe detector and measured for [21600s] [7]. The concentration of uranium, thorium and potassium were calculated using the formula discussed elsewhere [5]. Conversion factors were used to convert ppm to Bqkg^{-1}. [^{238}U; 1ppm = 12.35 Bq kg^{-1}; ^{232}Th; 1ppm= 4.06 Bq kg^{-1}]. Whereas 1% of ^{40}K = 313 Bq kg^{-1} [7].

4. Results and Discussion

The measured activity concentrations of ^{40}K, nuclides from ^{232}Th series (^{208}Tl, ^{228}Ac) and ^{238}U series (^{214}Pb, ^{214}Bi with ^{226}Ra) in investigated rock samples are presented. ^{238}U activity concentrations were calculated as the arithmetic means of the activities of 214Pb and ^{214}Bi isotopes. In the Table 1 concentrations of ^{40}K (%), ^{232}Th and ^{238}U (ppm) in measured samples calculated using conversion factors given by [8]. The ^{232}Th and ^{238}U concentrations are based on the ^{238}Ac and ^{226}Ra activity concentrations respectively. For all rocks Th/U ratio was calculated.

As shown in Table 2, the highest value refers to the sample layer, S1L3 (1195 ±151 Bq kg-1). The range varies from 236 ± 32 Bq kg^{-1} to 1195 ± 151 Bq kg^{-1} in the borehole layers. The percentage is higher in layer, SL3 (3.82%).

Table 1. The elemental Concentration of ^{238}U, ^{232}Th (ppm) and ^{40}K (%) in Dei-Dei borehole

No.	Sample	Weight (g)	Concentration (ppm)		%	
			^{238}U	^{232}Th	^{40}K	Th/U Ratio
1	S1L1	503.35	2.74 ± 0.26	13 ± 1	0.81 ± 0.10	4.75
2	S1L2	520.20	2.15 ± 0.21	11 ± 1	1.33 ± 0.16	5.19
3	S1L3	512.75	2.21 ± 0.21	13 ± 1	3.82 ± 0.48	5.73
4	S1L4	584.48	2.16 ± 0.21	14 ± 1	1.92 ± 0.24	6.39
5	S1L5	529.82	2.99 ± 0.29	18 ± 1	2.56 ± 0.32	5.87
6	S1L6	544.02	2.78 ± 0.27	16 ± 1	2.65 ± 0.33	5.92
7	S1L7	503.22	3.00 ± 0.29	19 ± 2	3.43 ± 0.43	6.35
8	S1L8	593.36	1.42 ± 0.14	11 ± 1	2.79 ± 0.35	8.05
9	S1L9	564.26	2.75 ± 0.26	24 ± 2	3.19 ± 0.40	8.59
10	S1L10	539.10	2.03 ± 0.20	19 ± 2	3.52 ± 0.44	9.45
11	S1L11	522.24	2.54 ± 0.20	24 ± 2	3.23 ± 0.44	9.49

Table 2. The Activity Concentration of ^{238}U, ^{232}Th and ^{40}K (Bq kg^{-1}) in Dei-Dei borehole

Sample ID	^{238}U	^{232}Th	^{40}K
S1L1	34 ± 3	53 ± 4	236 ± 32
S1L2	27 ± 3	45 ± 2	415 ± 53
S1L3	27 ± 3	51 ± 4	1195 ±151
S1L4	26 ± 3	56 ± 4	601 ± 76
S1L5	37 ± 4	71 ± 6	800 ± 101
S1L6	34 ± 3	67 ± 5	828 ± 104
S1L7	37 ± 4	77 ± 6	1073 ± 135
S1L8	18 ± 2	46 ± 4	874 ± 110
S1L9	34 ± 3	96 ± 8	997 ± 125
S1L10	25 ± 2	78 ± 6	1101 ±139
S1L11	31 ± 2	98 ± 6	1010 ± 139
Mean	30 ± 3	67 ± 5	830 ± 103

Data presented in Table 2 shows that radioactive equilibrium between progenies in ^{232}Th series for all rock samples can be assumed. The higher value refers to the sample from the depth to the bottom of aquifer bearing formation (S1L11), with the activity concentration of ^{228}Ac (^{232}Th) higher, (98 ± 6 Bq kg^{-1}).The effect in groundwater should be investigated. The highest measured value of ^{288}Ac (^{232}Th) activity concentration exceeds the average activity concentration refers to the continental crust almost twice (S1L11), [9]. It could be that the activity concentration of natural radionuclides in rocks are connected to radionuclides in groundwater which reacts with soil and bedrock and release quantities of dissolved components, depending on the mineralogical and geochemical composition of the soil and rock, redox conditions and the residence time of groundwater in the soil and bedrock.

Measured rocks are characterized by radioactivity of ^{226}Ra (^{238}U). The highest values refer to the samples collected from the S1L5 and S1L7, (37 ± 4 Bq kg^{-1} and 37± 4 Bq K kg^{-1}) respectively. It can be observed in Table 1 that the Th/U ratio increases linearly with depth.

5. Conclusion

In this study, it is noted that concentration of ^{232}Th and ^{238}U in measured rocks depend on the nature of the intrusive materials with magmatic and its relationship with granitic gneiss intrusions; which may be connected to groundwater also. Due to the interconnectivity of fractures in the study area from the SRTM lineament map, it could be that the activity concentration of natural radionuclides in rocks is connected to radionuclides in groundwater which reacts with soil and bedrock, release quantities of dissolved components, depending on the mineralogical and geochemical composition of the soil and rock. This will help professionals in hydrogeology and water resources management: civil engineers, environmental engineers, geologists and hydrologists who are engaged in the investigation, management, and protection of groundwater resources on areas to drill and not to drill hydrogeologically motivated boreholes. The activity levels are within the limit and recommend further research within groundwater activity concentrations and geochemistry of both water and rocks in the area.

Acknowledgement

The authors would like to thank the ministry of Higher Education (MOHE) for their funding through Universiti Teknologi Malaysia Research Grant Scheme Project number: Q.J130000.2526.03H28.

References

[1] Tzortzis, M., Tsertos, H. (2004). Determination of thorium, uranium and potassium elemental concentrations in surface soils in Cyprus. Journal of Environmental Radioactivity, 77, 325-338.

[2] Xinwei, L., Xiaolon, Z. (2008). Natural radioactivity measurements in Rock samples of Chihua Mountain National Geological Park, China. Radiation Protection Dosimetry, 128,77-82

[3] Lee, S.K., H. Wagiran, Ahmad T. R, Nursama H. A and A. K. Wood. (2009). Radiological Monitoring: Terrestrial Natural Radionuclides in Kinta District, Perak, Malaysia. Journal of Environmental Radioactivity, 100, 368-374.

[4] Ajibade,A.C., Woakes, M and Rahaman,M.A.,1978. Proterozoic crustaldevelopment in the Pan-African regime of Nigeria.In Prot. lithos.Evol. Geody,17,259-271.

[5] Maxwell, O., H. Wagiran, N. Ibrahim, S,K, Lee, S. Soheil.(2013). Comparison of ^{238}U, ^{232}Th, and ^{40}K in different layers of subsurface structuresion Dei-Dei and Kubwa, Abuja, Northcentral Nigeria. Radiation Physics and Chemistry, 91, 70-80.

[6] Omeje M., Husin W., Noorddin I., Oha I.A., Onwuka O.S, Ugwuoke P.E and Meludu O. (2013). Geoelectrical investigation of Aquifer problem in Gosa area of Abuja, North Central Nigeria.Vol.8 (13) pp. 549-559.

[7] Omeje, M., H. Wagiran, N. Ibrahim, S. K, Lee, S. Soheil. (2013). Measurement of ^{238}U, ^{232}Th, and ^{40}K in boreholes at Gosa and Lugbe, Abuja, North Central Africa. Radiation Protection Dosimetry, 157(2) 271-277.

[8] International Atomic Energy Agency (IEAE),1989. Construction and use of calibration Facilities for Radiometric Field Equipment. Technical Reports Series no.309, IAEA, Vienna

[9] Eisenbud, M. and Gesell, T., 1997. Environmental Radioactivity from Natural,Industrial and MilitarySources, Acad. press, San Diego, CA, 134-200